Experimental Carbonation of Serpentine, Olivine, and Brucite

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Numerous methods have been proposed for sequestrating CO_2, captured directly from the burning of fossil fuel or indirectly from the atmosphere, and many of these methods leave CO_2 as a gas or supercritical fluid. In contrast, we have been pursuing a method to convert the CO_2 into a benign, immobile solid-waste form, specifically a carbonate. At laboratory-scale, we are testing ultramafic rocks (those that contain magnesium silicates), which offer great potential as a raw material for converting CO_2 into a magnesium carbonate. These rocks are abundantly distributed along the eastern and western U.S. and in parts of the interior. The rocks are high grade with respect to MgO, and the magnesium is thermodynamically easier to extract from silicates than is calcium (the other abundant potential resource for this process).

We are investigating a number of approaches to converting CO_2 and serpentinites into carbonate. Our experiments mimic either an industrial reaction process (in which the serpentinite would be mined, reacted, and replaced into the mine) or in an in situ process (in which the CO_2 is emplaced in a permeable unit associated with a reactive ultramafic).

Our team is focusing on three common minerals in serpentinite: serpentine, olivine (forsterite), and brucite. We use autoclaves and batch reaction vessels to expose the specific mineral to CO_2, either in an aqueous environment or a dominantly CO_2-fluid environment. Based on thermodynamic calculations for the multiphase system at $T < 600$ºC and $P < 0.5$ kbar, we have identified optimum conditions for various carbonation pathways. Brucite reacts readily and rapidly under most conditions we have investigated experimentally. Not surprisingly, olivine and serpentine are more difficult to carbonate. We are currently investigating reaction pathways and catalysts for enhancing the carbonation process for these and other Mg-silicates.

Evaluating Ultramafic Resources

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In this project, we are assessing the resource potential of ultramafic bodies as sources of magnesium for CO_2 sequestration. Following a general evaluation of types of ultramafic rocks and their worldwide distribution, we evaluated two sites in California (Del Puerto and Wilbur Springs) and sites in the Appalachian Mountains and Puerto Rico for ultramafic rock volumes and magnesium content. We also organized a field trip to California to introduce nongeologists on the Carbon Management project to the geology, structure, alterations, and fluids associated with ultramafic bodies (serpentinite, peridotite, and silica-carbonate rock).

We are now evaluating serpentinite-bearing diatreme deposits on the Navajo Nation for CO_2 sequestration. We have collected data on the geology, structure, areal distribution, approximate thickness, chemical composition, mineralogy, and acid dissolution properties of the ultramafic bodies. Using this data, we calculate the volume of ultramafic rock in place and multiply by the wt% MgO to assess the quantity of ultramafic rock needed to sequester the CO_2 produced by U.S. populations (usually 1 million people), assuming average current CO_2 emissions.

Sequestration of CO_2 in a Depleted Oil Reservoir

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Sequestration of CO_2 in depleted oil reservoirs is another viable option for carbon management. Our objective is to initiate a comprehensive suite of computer simulations, laboratory tests, and field measurements to understand, predict, and monitor the coupled geomechanical, geochemical, and hydrogeologic processes associated with downhole injection of CO_2 into a depleted oil reservoir.

Using the West Pearl Queen Reservoir near Hobbs, New Mexico, which is not in operation, we are aiming to understand, predict, and monitor the migration and ultimate fate of injected CO_2 at a micropilot-scale field experiment (pump-in/pump-out scheme). Data from these fields will provide us with a unique opportunity to test, refine, and calibrate our computer model. We will use both geophysical and geochemical techniques to monitor the transport and fate of the injected CO_2 plume. Ultimately, the models and data will be used to predict storage capacity and physical and chemical changes in reservoir properties such as fluid composition, porosity, permeability, and phase relations. Technological gaps related to the engineering aspects of CO_2 sequestration would also be identified in the course of this study.

During the first nine months of our research, we developed a geologic model (from well-log and core data) for the target interval of the West Pearl Queen Reservoir. Using the geologic model, we developed a flow-simulation model; on the basis of the flow model, we conducted a production-history match. A number of properties, including the rock-fluid interaction parameters (relative-permeability), were determined by calibration techniques, based on how well the simulation results matched the past production data. Once a satisfactory history match was obtained, the model was used to determine the effect of injecting CO_2, which was injected at the end of the history-matching period. Using multiple injection scenarios and varying injection rates, we found that CO_2 could be injected with the pressure in the reservoir, which is below state regulations, as well as rock-fracture pressure. We are now moving toward Phase II, designing and performing CO_2 injection in the reservoir.

Zero-Emission Coal Technology

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We are investigating a new zero-emission technology for coal-fueled power plants. This new combustion-free technology converts coal to electricity with a factor-of-two improvement in efficiency compared to conventional power plants, thereby doubling the life of our coal reserves. The process simultaneously separates out the product CO_2 as a pure gas stream. This CO_2 is permanently sequestered by reacting it with abundant magnesium silicate ores to form a solid mineral. This project is discussed in detail in the Research Highlights section.